CAFA: A COMPUTER-AIDED CURVE-FIT AND ANALYSIS PROGRAM

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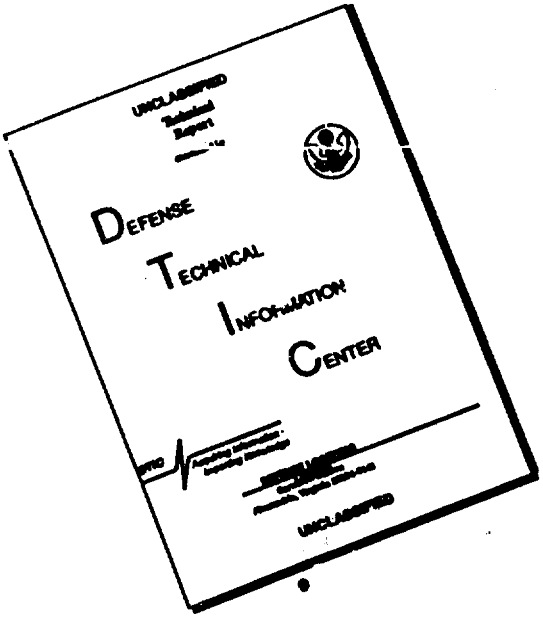

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ABSTRACT

The theoretical basis for the CAFA program is discussed. An approximate technique evolving from the theory is applied to the analysis of the current-voltage characteristic of a hypothetical diode, with good results. A printout of the resultant program and data is included.

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INTRODUCTION

The CAFA (Computer-Aided Fit and Analysis; pronounced "café") program was developed for fitting smooth curves to experimental current-voltage and similar data and for using the curves obtained to analyze the data. The original goal was to allow the slope of such curves to be obtained at any point in order to assist in determining the current mechanisms existing in solid-state devices. The program was found to be useful for several other purposes. One, in particular, allowed interpolation between data points. The preliminary results obtained have been encouraging. The program was used extensively to analyze the data discussed in Reference 1.

The subroutine which makes the program possible is the SMOOTH subroutine originally developed by Reinsch (1967), adapted for Fortran by R. E. Jones of Sandia Laboratories, and modified by the author to include interpolation. This subroutine fits a series of spline (cubic) functions to the data points and smooths the transitions between functions by requiring continuity of the first and second derivatives within a certain error chosen by the user. The first and second derivatives are available as printout in addition to the fitted data points and the coefficients of each cubic equation. The latter permitted interpolation between data points. Examination of the program, Fig. 2, reveals the use of these features.

Several general approaches to determining current mechanisms from the CAFA program are discussed below, along with the specialized version used in this study.

THEORETICAL BACKGROUND

Suppose the current in a diode, I, is given by

$$I = I_o \exp(\beta V/m) \quad , \tag{1}$$

where I_o is constant, $\beta = q/kT$, V is the applied voltage, and m has a constant value.* In this case, the current in the diode is described by one mechanism and the slope of the ln(I) vs. V curve is

$$\frac{\partial \ln(I)}{\partial V} = \frac{\beta I}{m} \quad . \tag{2}$$

Since everything in Eq. (2) is known except m, m can be determined and the current mechanism can often (but not always) be identified. Unfortunately, total diode currents given by Eq. (1) usually do not exist in practice. The current in real diodes is more often given by an expression of the form

$$I = \sum_i I_{oi} \exp(\beta V/m_i) + \sum_j I_{oj} \exp(V/\phi_j) \quad , \tag{3}$$

where m_i describes the ith temperature-dependent mechanism (e.g., diffusion, space-charge region recombination, surface) and ϕ_j describes the jth nontemperature-dependent mechanism (e.g., tunneling). Even Eq. (3) does not describe the most general current form because it neglects nonlinear effects, such as interactions between current components, plus it assumes all the I_o's are constant and that $V = V_j$, the junction voltage. Nevertheless, Eq. (2) is often an excellent approximation. For real diodes, one often does not know what the current mechanisms are but could deduce the mechanisms if the m_i's in Eq. (3) were known. If, however, the diode current consists of only two components and is of the form

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*To be perfectly general, "current" should be replaced by "flux" and "voltage" should be replaced by "force."

$$I = I_{01} \exp(\frac{\beta V}{m_1}) + I_{02} \exp(\frac{\beta V}{m_2}) , \tag{4}$$

then

$$\frac{\partial \ln(I)}{\partial V} = \frac{\beta}{I}(\frac{1}{m_1} + \frac{1}{m_2}) , \tag{5}$$

and the two values of m cannot be determined easily unless each current type has a clearly defined region of dominance and the experimenter has data covering those regions. Even the simple case of Eq. (5) is not usually seen in practical diodes. To further complicate matters, the value of m describing one mechanism may vary; as an example $2 \leq m < \infty$, depending on injection level, for donor-acceptor pair (DAP) recombination in the space-charge region.[2] A method for finding the value of m at any point, given a current-voltage curve, is therefore desirable. A graphical approach suffers on several counts: It is not accurate enough unless the ln(I) vs. V curve is quite linear, as will be seen below; and it is extremely tedious and time consuming to obtain m at many points. The numerical approach discussed here is quick and gives good results for the special cases discussed.

Given an experimental current-voltage curve in which the current is presumed to arise from the mechanisms described in Eq. (3), we assume that the current at any point on the curve can be written as

$$I = I_o \exp\left(\frac{\beta V}{m(I)}\right) . \tag{6}$$

Thus, our basic assumption is that the experimentally-determined current given by Eq. (6) is equivalent to the theoretical current given by Eq. (3). The parameter that allows Eq. (6) to describe the current at any point is, of course, m(I). If m(I) is constant, Eq. (6) reduces to Eq. (1). The slope obtained from Eq. (6) is

$$\frac{\partial I}{\partial V} = \beta I \frac{\partial}{\partial V}\left(\frac{V}{m(I)}\right) . \tag{7}$$

But $m(I) = m(V)$ implicitly, since $I \propto V$. That is,

$$\frac{\partial}{\partial V} \frac{V}{m(I)} = V \frac{\partial}{\partial V} \frac{1}{m(I)} + \frac{1}{m(I)} \frac{\partial V}{\partial V} ,$$

or

$$\frac{\partial}{\partial V} \frac{V}{m(I)} = V \left[- \frac{1}{m(I)^2} \frac{\partial m(I)}{\partial I} \frac{\partial I}{\partial V} \right] + \frac{1}{m(I)} . \tag{8}$$

The dependence of m on I will be understood unless otherwise stated.

A differential equation can be obtained that would solve for m in closed form if a closed form solution exists for the differential equation. By combining Eqs. (8) and (7) we obtain

$$\frac{\partial I}{\partial V} = \frac{\beta I}{m + \frac{\beta I V}{m}\frac{\partial m}{\partial I}} \quad . \qquad (9)$$

By rearranging Eq. (9) we obtain, since $\partial m/\partial I = dm/dI$ (m is a function only of the current at constant temperature),

$$\frac{dm}{dI} + \frac{1}{\beta I V} m^2 - \frac{1}{V \partial I/\partial V} = 0 \quad . \qquad (10)$$

This is a very nonlinear d.e. of the form

$$\frac{dy}{dx} + \frac{y^2}{axz} - \frac{y}{bz} = 0 \quad , \qquad (11)$$

where $x = x(z)$ is known and b ($= \partial I/\partial V$) is known. The d.e. might be solvable using numerical techniques.

We shall briefly discuss the errors which result when the nonlinearity in Eq. (7) is assumed negligible. Considering the derivative on the right-hand side,

$$\frac{\partial}{\partial V}\left(\frac{V}{m}\right) = -\frac{V}{m^2}\frac{\partial m}{\partial V} + \frac{1}{m} \quad , \qquad (12)$$

which is

$$\frac{\partial}{\partial V}\left(\frac{V}{m}\right) \approx \frac{1}{m} \qquad (13)$$

if $\partial m/\partial V$ is negligible. This requires

$$\frac{1}{m} >> - \frac{V}{m^2} \frac{\partial m}{\partial V} \quad ,$$

so that

$$m >> - V \frac{\partial m}{\partial V} \quad . \qquad (14)$$

For $m \approx 2$, $V \approx 1$ volt,

$$\left| \frac{\partial m}{\partial V} \right| << 2 \text{ units/volt.} \qquad (15)$$

The rate of change of m with V must be very small for this condition not to be violated. Hence, the approximation that $\partial m/\partial V$ is negligible is often not valid. This approximation is numerically identical to that obtained using an incremental approach which approximates the curve between a series of closely adjacent data points by a set of straight lines, and is approximately equivalent to the results which would be obtained using a graphical technique. Therefore, unless a ln(I) vs. V curve is very linear, a graphical or incremental approach, or an approach which neglects $\partial m/\partial V$ will not suffice for determining the value of m from an experimental curve.

As a special case of the relationship between Eqs. (3) and (6) we write the relation as

$$I = I_0 \exp\left(\frac{\beta V}{m}\right) = I_{01} \exp\left(\frac{\beta V}{m_1}\right) + I_{02} \exp\left(\frac{\beta V}{m_2}\right) . \qquad (16)$$

The two terms on the right-hand side of Eq. (16) may be considered as two distinct components or as one distinct component plus a sum of other components, so that the relation is not necessarily restricted to only two distinct components. This will be called the "two-process" model. We shall assume Eq. (16) holds and determine the effective m vs. V for various ratios R,

$$R \equiv I_{01}/I_{02} \ . \tag{17}$$

R will be constant or nearly so for many situations. Using Eq. (17) we can rewrite Eq. (16) as

$$I = I_{02}\left[R \exp\left(\frac{\beta V}{m_1}\right) + \exp\left(\frac{\beta V}{m_2}\right)\right] . \tag{18}$$

The derivative is

$$\frac{\partial I}{\partial V} = I_{02}\left[\frac{R\beta}{m_1} \exp\left(\frac{\beta V}{m_1}\right) + \frac{\beta}{m_2} \exp\left(\frac{\beta V}{m_2}\right)\right] . \tag{19}$$

Define

$$f \equiv \frac{I}{\partial I/\partial V} \ ; \tag{20}$$

combining Eqs. (18) and (19) gives

$$f = \frac{R \exp\left(\frac{\beta V}{m_1}\right) + \exp\left(\frac{\beta V}{m_2}\right)}{\beta\left[\frac{R}{m_1} \exp\left(\frac{\beta V}{m_1}\right) + \frac{1}{m_2} \exp\left(\frac{\beta V}{m_2}\right)\right]} . \tag{21}$$

Equation (21) can be solved for R:

$$R = - \frac{\frac{\beta f}{m_2} - 1}{\frac{\beta f}{m_1} - 1} \exp\left[\beta V\left(\frac{1}{m_2} - \frac{1}{m_1}\right)\right] . \tag{22}$$

Since R is constant with V, we must have

$$\frac{\partial R}{\partial V} = 0 . \tag{23}$$

Performing the indicated operations on Eq. (22), realizing that $\exp\left[\beta V\left(\frac{1}{m_2} - \frac{1}{m_1}\right)\right] \not\equiv 0$, and rearranging gives

$$\frac{\partial f}{\partial V} = \left(\frac{\beta f}{m_2} - 1\right)\left(\frac{\beta f}{m_1} - 1\right) . \tag{24}$$

This is the criterion for R to be constant. One way to use Eq. (24) would be to find f(V) (from the results of curve-fitting to the I-V characteristic using the SMOOTH subroutine, since this gives $\partial I/\partial V$ also), curve fit to the points f, find $\partial f/\partial V$ from the curve fit and plot the right-hand side and $\partial f/\partial V$ vs. βf on the same curve, using m_1 and m_2 as parameters; one could inspect the results to find integer values of m_1 and m_2 such that the curves intersect. Another way would be to find a second expression describing $\partial f/\partial V$. By differentiating Eq. (20) directly, we obtain

$$\frac{\partial f}{\partial V} = 1 - \frac{I}{(\partial I/\partial V)^2} \frac{\partial^2 I}{\partial V^2} . \tag{25}$$

Since the second derivatives can also be obtained from the curve fit of I vs. V, we have enough information to find $\partial f/\partial V$;

that is, if the second derivatives are reasonably well behaved. A third method is to rearrange Eq. (24), if $\partial f/\partial V$ can be found, to obtain

$$\beta f = \frac{m_1 + m_2}{2} \quad \frac{1}{2}\sqrt{(m_1 + m_2)^2 - 4m_1m_2(1 - \frac{\partial f}{\partial V})} . \tag{26}$$

Both sides of Eq. (26) can be plotted vs. V with m_1 and m_2 as parameters. The solutions would be obtained at the curve intersections. For the special case when $\partial f/\partial V = 0$, Eq. (26) reduces to

$$\beta f = m_1 \text{ or } m_2 . \tag{27}$$

Thus, one of the m's can be found if $\partial f/\partial V = 0$ somewhere. If $\partial f/\partial V = 1$,

$$\beta f = m_1 + m_2 \text{ or } 0 \quad . \tag{28}$$

If $\partial f/\partial V = 1$ and $\beta f \neq 0$, then

$$m_2 = \beta f - m_1$$

if m_1 was found at a point where $\partial f/\partial V = 0$. Still another approach uses f in the differential equation (10). Using the definition of f, Eq. (10) becomes

$$V \frac{dm}{dV} = m - \frac{m^2}{\beta f} . \tag{29}$$

If βf is a determinable function, this can be solved to get a family of curves for various V's. Even if f is not a determinable function, the expression (26) could be substituted into the d.e. and then one would have a d.e. in terms of m, m_1, and m_2, so that m could be predicted given m_1 and m_2 (a trial-and-error approach). For the special case when $\partial f/\partial V = 1$, the d.e. becomes

$$\frac{dm}{dV} = \frac{1}{V}\left(m - \frac{m^2}{m_1 + m_2}\right) , \qquad (30)$$

where we have used Eq. (28) with $\beta f \neq 0$. This can be solved, yielding

$$\frac{m^2 - m_o^2}{2} - \frac{m^3 - m_o^3}{3(m_1 + m_2)} = \ln\left(\frac{V}{V_o}\right) , \qquad (31)$$

where m_o is a known value of m at $V = V_o$. This transcendental equation may also be solved graphically.

A somewhat simpler and less tedious approximate approach to determining m_1 and m_2 has been developed and will be discussed next. The approach is useful in a transition region or any region where superposition of two or more current components results in some curvature of the experimental ln(I) vs. V curve.

AN APPROXIMATE APPROACH

If the two-process model, Eq. (16), is valid, and if the ln(I) vs. V curve is nonlinear, one may obtain a pair of equations (24) for each two adjacent data points. If the curve is nearly linear, the pair of equations thus obtained may not be linearly independent or may not have a solution, so that the procedure described here will not work in such a region. If a linearly independent pair of equations is obtained, each pair has a unique solution from which the m's can be determined approximately. Since each such pair has a unique solution whether or not the two- or one-process model is valid, values of m can be determined, but these may not be the integer values expected. We define

$$G \equiv 1 - \frac{\partial f}{\partial V} , \tag{32}$$

$$RPM \equiv \frac{1}{m_1 m_2} , \tag{33}$$

(the reciprocal product of m's), and

$$SRM = \frac{m_1 + m_2}{m_1 m_2} \tag{34}$$

(the sum of reciprocals of m's). These symbols are useful computer words. Let I and I + 1 be adjacent data points and look for the Jth solution of the pair of equations obtained from Eq. (24). To be compatible with computer language, let $\beta f \rightarrow BF$

and $(\beta f)^2 \rightarrow BF2$. Also rewrite Eq. (24) as

$$G = 1 - \frac{\partial f}{\partial V} = \left(\frac{m_1 + m_2}{m_1 m_2}\right) \beta f - \frac{1}{m_1 m_2} (\beta f)^2 \tag{35}$$

Then

$$BF(I)SRM(J) - BF2(I)RPM(J) = G(I) \tag{36}$$

and

$$BF(I+1)SRM(J) - BF2(I+1)RPM(J) = G(I+1) \tag{37}$$

to a good approximation. The solution of this pair of equations is

$$SRM(J) = \frac{BF2(I+1)G(I) - BF2(I)G(I+1)}{BF(I)BF2(I+1) - BF(I+1)BF2(I)} \tag{38}$$

and

$$RPM(J) = \frac{BF(I+1)G(I) - BF(I)G(I+1)}{BF(I)BF2(I+1) - BF(I+1)BF2(I)} . \tag{39}$$

Letting $XM2 \equiv m_2$ and $XM1 \equiv m_1$,

$$XM2(J) = \frac{SRM(J)}{2RPM(J)} - \frac{1}{2RPM(J)} \sqrt{[SRM(J)]^2 - 4RPM(J)} \tag{40}$$

and

$$XM1(J) = \frac{SRM(J)}{RPM(J)} - XM2(J) . \tag{41}$$

Once the m's have been obtained, there are nine possible combinations (which will not be enumerated) of results, wherein m_1

and m_2 are constants of correct value (i.e., integers), constants of incorrect value, or variables. If one of the m's = 1, the current component may be injection current. If so, its correct I_o can be found as described below. If the other m is, say, 2, where the 2 is found to describe space-charge region recombination current, the I_o found for it may vary, because I_o for such current is, in general, injection-level dependent. This will complicate the results somewhat, but judicious inspection may help in deciphering the results. For any case where one of the m's is not constant, the value of I_o obtained may be treated as a "subtotal" current of the form

$$I_{oi} = I_{oi}' \exp(\frac{\beta V}{m}) \quad , \tag{42}$$

where m = m(I). It is possible to treat this subtotal current in the same fashion as the total current: Curve fit to it, assume two current mechanisms and break it up into m_1' and m_2', as before, continuing until the currents have been resolved satisfactorily. The foregoing also applies to any case where one of the m's is constant but incorrect.

In any case, when values of m_1 and m_2 have been obtained, we write

$$I = I_{01} \exp(\frac{\beta V}{m_1}) + I_{02} \exp(\frac{\beta V}{m_2}) \quad . \tag{43}$$

For two adjacent interpolated data points J and J+1, we have

$$I(J) = I_{01}(J)\ \exp\left(\frac{\beta V(J)}{m_1}\right) + I_{02}(J)\ \exp\left(\frac{\beta V(J)}{m_2}\right) \qquad (44)$$

and

$$I(J+1) = I_{01}(J)\ \exp\left(\frac{\beta V(J+1)}{m_1}\right) + I_{02}(J)\ \exp\left(\frac{\beta V(J+1)}{m_2}\right) \qquad (45)$$

to a good approximation, because the I_{oi}'s should be nearly constant between two closely adjacent data points. This pair of simultaneous equations can be solved for $I_{01}(J)$ and $I_{02}(J)$. If $I_{01}(J) = I_{01}(J+1)$, the answers are exact (this will be the case for $m_i = 1$, for example) if the m's are exact. If $I_{01}(J) \neq I_{01}(J+1)$, it does not matter, since a better value will be found on the second iteration. The solutions of Eqs. (44) and (45) are

$$I_{01}(J) = \frac{I(J)\ \exp\left(\frac{\beta\Delta V}{m_2}\right) - I(J+1)}{\exp\left(\frac{\beta V(J)}{m_1}\right)\left[\exp\left(\beta\Delta V\left(\frac{1}{m_2} - \frac{1}{m_1}\right)\right)\right]} \qquad (46)$$

and

$$I_{02}(J) = \frac{I(J+1) - I(J)\ \exp\left(\frac{\beta\Delta V}{m_1}\right)}{\exp\left(\frac{\beta V(J)}{m_2}\right)\left[\exp\left(\beta\Delta V\left(\frac{1}{m_2} - \frac{1}{m_1}\right)\right)\right]} \qquad (47)$$

where

$$\Delta V \equiv V(J+1) - V(J) \qquad (48)$$

and we have assumed m_1 and m_2 do not change much between J and J + 1.

To demonstrate two of the approaches which have been used successfully[1] and to test their validity, data from a hypothetical diode were analyzed by the program. This diode had $m_1 = 1$, $m_2 = 2$, $I_{01} = 10^{-8}$ units and $I_{02} = 1$ unit. Its I-V characteristic is plotted in Fig. 1. The resultant computer printout is given in Fig. 2.

In the lowermost and uppermost portions of the curve, where m_2 and m_1, respectively, dominate, Eq. (2) is an excellent approximation. Hence, XM or XMPRIM describes the current mechanisms very well and one could deduce the components easily for this diode. PPRIM is equivalent to I_o and it is seen to give the correct values at either end of the range.

For the transition region near the center of the curve, the value of m as calculated from Eq. (2) does not give the correct value, as expected. In this region (roughly from subscripts I = 50 to I = 70), the approach using Eqs. (36) through (41) finds its application and the values of m_1 and m_2 are determined with good accuracy in this region. Note also that Eq. (27) can be used to find m_1 and m_2 at the two extremes, since βf (called BFP) $\simeq 1$ at either end of the curve. The experimental results from real diodes usually do not show large regions of linearity in which Eq. (2) is useful, so that the utility of the latter approach in regions of curvature becomes very apparent. This approach does not work well in the linear

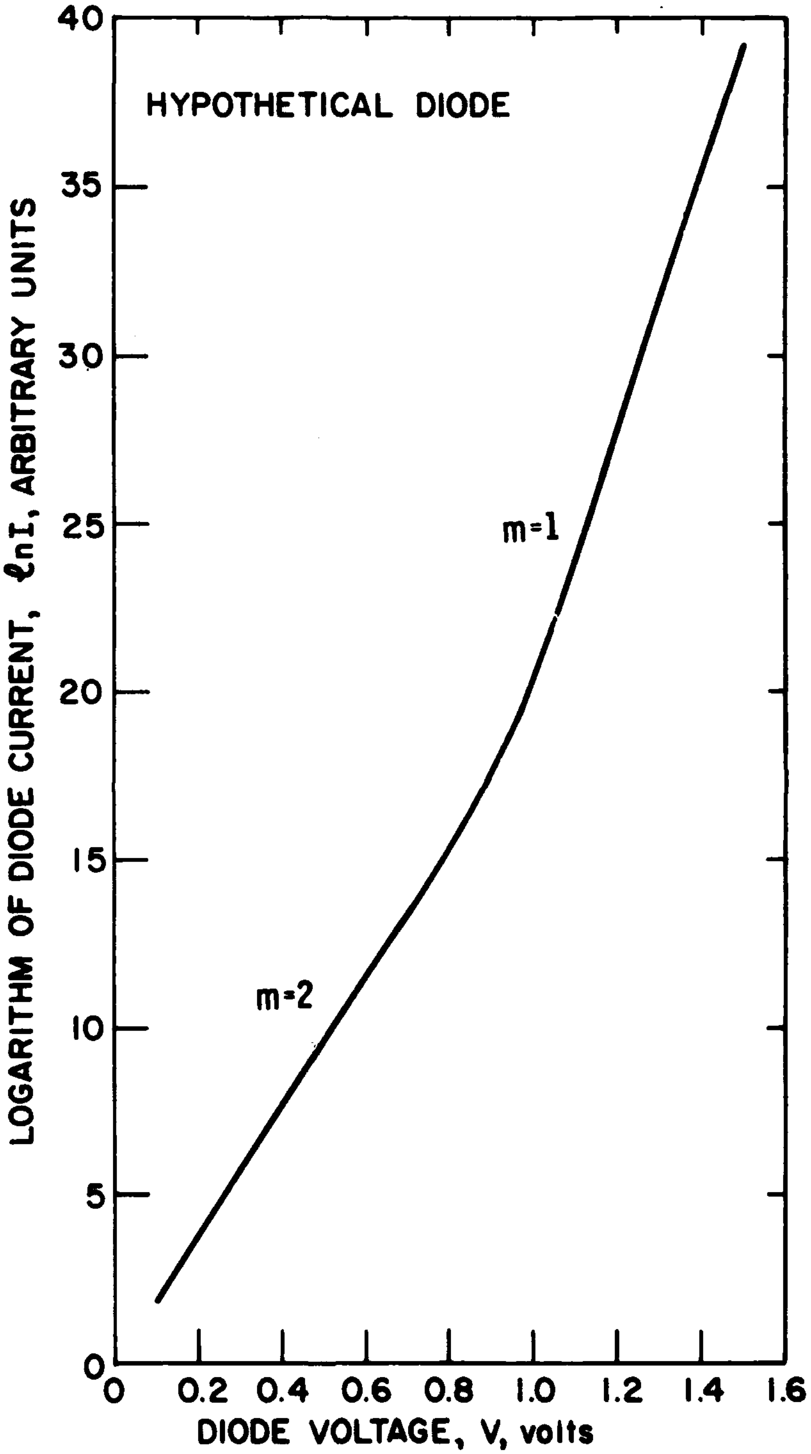
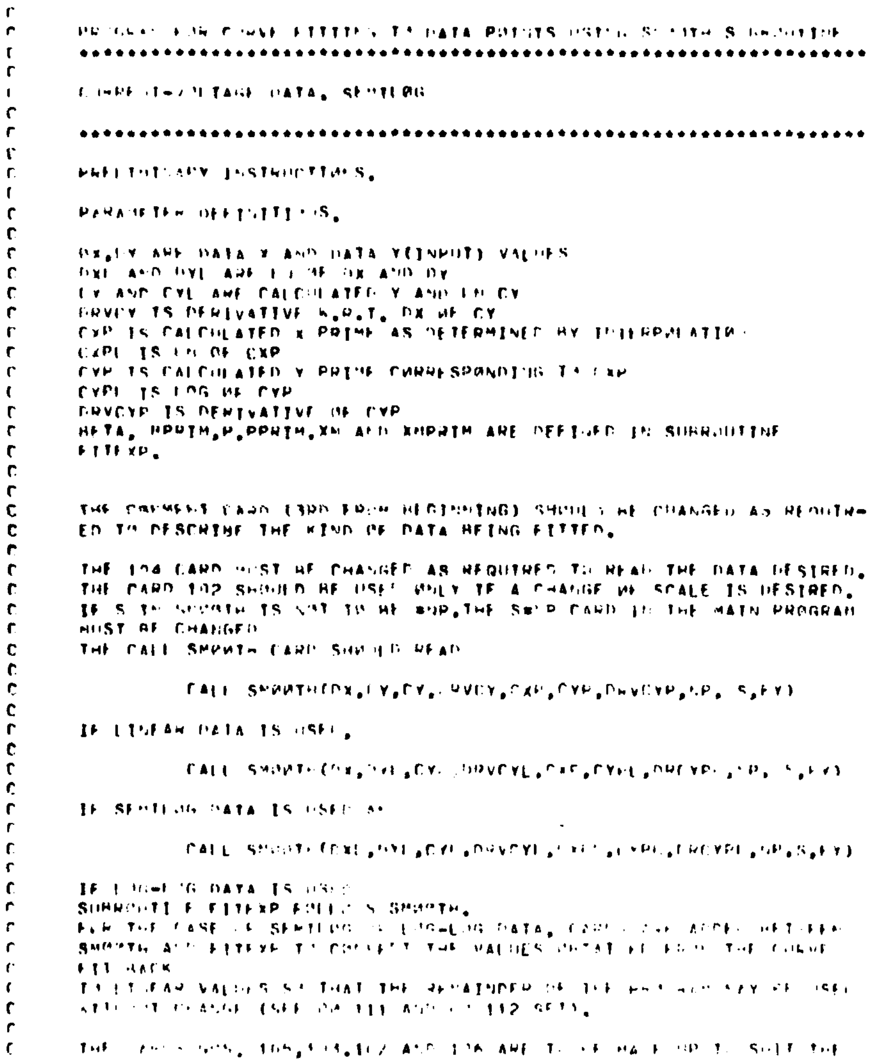


Figure 1. Current-voltage Characteristic of a Hypothetical Diode

regions, as discussed earlier. The values obtained in the nonlinear region for I_{01} and I_{02} (called CY01 and CY02 or CY01P and CY02P in the program) are not as satisfactory as those obtained for m_1 and m_2. The least error occurs where m_1 (or m_2) passes through its correct value. In this case the error may be negligible (less than 1%), but it may be off by a factor of two or three; however, it is well within an order of magnitude in the worst case, and this would often be adequate. If there is a linear region where m_1 or m_2 is determined correctly, I_{01} and I_{02} will always be calculated within ±20%.

At present, the CAFA program is in a primitive stage of development. Further work should provide a more useful, accurate and flexible program which will be of considerable value in experimental research.



```
C
C      PROGRAM FOR CURVE FITTING TO DATA POINTS USING SMITH S ROUTINE
C      *****************************************************************
C
C      CURRENT-VOLTAGE DATA, SEMILOG
C
C      *****************************************************************
C
C      PRELIMINARY INSTRUCTIONS.
C
C      PARAMETER DEFINITIONS.
C
C      DX,DY ARE DATA X AND DATA Y(INPUT) VALUES
C      DXL AND DYL ARE LN OF DX AND DY
C      CY AND CYL ARE CALCULATED Y AND LN CY
C      DRVCY IS DERIVATIVE W.R.T. DX OF CY
C      CXP IS CALCULATED X PRIME AS DETERMINED BY INTERPOLATION
C      CXPL IS LN OF CXP
C      CYP IS CALCULATED Y PRIME CORRESPONDING TO CXP
C      CYPL IS LOG OF CYP
C      DRVCYP IS DERIVATIVE OF CYP
C      BETA, BPRIM,P,PPRIM,XM AND XMPRIM ARE DEFINED IN SUBROUTINE
C      FITEXP.
C
C
C      THE COMMENT CARD (3RD FROM BEGINNING) SHOULD BE CHANGED AS REQUIR-
C      ED TO DESCRIBE THE KIND OF DATA BEING FITTED.
C
C      THE 104 CARD MUST BE CHANGED AS REQUIRED TO READ THE DATA DESIRED.
C      THE CARD 102 SHOULD BE USED ONLY IF A CHANGE OF SCALE IS DESIRED.
C      IF S IN SMOOTH IS NOT TO BE [illegible],THE S=[illegible] CARD IN THE MAIN PROGRAM
C      MUST BE CHANGED
C      THE CALL SMOOTH CARD SHOULD READ
C
C              CALL SMOOTH(DX,DY,CY,DRVCY,CXP,CYP,DRVCYP,NP, S,FY)
C
C      IF LINEAR DATA IS USED,
C
C              CALL SMOOTH(DX,DYL,CY,DRVCYL,CXP,CYPL,DRCYP ,NP, S,FY)
C
C      IF SEMILOG DATA IS USED AS
C
C              CALL SMOOTH(DXL,DYL,CYL,DRVCYL,CXPL,CYPL,DRCYPL,NP,S,FY)
C
C      IF LOG-LOG DATA IS USED
C      SUBROUTINE FITEXP FOLLOWS SMOOTH.
C      FOR THE CASE OF SEMILOG OR LOG-LOG DATA, CARDS ARE ADDED BETWEEN
C      SMOOTH AND FITEXP TO CONVERT THE VALUES OBTAINED FROM THE CURVE
C      FIT BACK
C      TO LINEAR VALUES SO THAT THE REMAINDER OF THE PROGRAM MAY BE USED
C      WITHOUT CHANGE (SEE CARD 111 AND [illegible] 112 [illegible]).
C
C      THE CARDS 105, 106,113,107 AND 136 ARE TO BE MADE UP TO SUIT THE
```

Figure 2. The CAFA Program. Printout for the Hypothetical Diode has been Included. The PLOTIT Plots have not been Included in order to Save Space.

NOT REPRODUCIBLE

NOT REPRODUCIBLE

```
C     INDIVIDUAL REQUIREMENTS OF THE PROGRAM AND DATA BEING FITTED, A
C     SIMILAR TREATMENT IS REQUIRED FOR CARDS 257,259,261 AND 260.
C
C     THE PLOTIT CARDS ARE CHANGED TO SUIT WHAT IS TO BE PLOTTED AND
C     THE STATION RANDOM DISC CARDS MUST BE CHANGED ACCORDINGLY.
C     FOR EXAMPLE, THE FIRST VARIABLE IN A PLOTIT CALL IS EITHER PDX
C     OR CXP FOR LINEAR OR SEMILOG DATA, AND IS EITHER PDXL OR CXPL FOR
C     LOG-LOG DATA. IF CALCOMP CALLS ARE USED, THESE MUST BE MODIFIED
C     TO SUIT EACH DATA SET.
C
C     DETERMINATION OF APPROPRIATE ERROR, EY(I).
C
C     SUBROUTINE SMOOTH REQUIRES AN OPTIMUM CHOICE OF EY(I) FOR THE
C     CURVE-FIT FUNCTION AND ITS DERIVATIVES TO BE SMOOTH SIMULTANE-
C     OUSLY. IF THE ERROR IS ZERO, THE CURVE FIT WILL BE NEARLY PERFECT
C     BUT THE DERIVATIVES WILL EXHIBIT NOISE. IF THE ERROR IS LARGE, THE
C     DERIVATIVES WILL BE SMOOTH BUT THE CURVE FIT WILL DETERIORATE.
C     AN OPTIMUM ERROR CAN BE FOUND BY TRIAL AND ERROR TO BE IN BETWEEN
C     THE TWO EXTREMES.
C     FOR CURRENT-VOLTAGE DATA OR SIMILAR DATA IN WHICH THE ORDINATE EX-
C     TENDS OVER SEVERAL ORDERS OF MAGNITUDE, THE ERROR SHOULD BE PRO-
C     PORTIONAL TO THE LOG OF THE ORDINATE.  AN ERROR
C
C                   EY(I)=0.0005*DYL(I)
C
C     HAS BEEN FOUND TO BE A GOOD COMPROMISE FOR CERTAIN I-V DATA.
C
      DIMENSION DZ(25)
      DIMENSION DX(25),DY(25),DXL(25),DYL(25)
      DIMENSION CY(25),CYL(25),P(25),BETA(25),XM(25),DRVCY(25),DRVCYL(25
     1)
      DIMENSION CXP(100),CYP(100),CXPL(100),CYPL(100),EPRTN(100),
     1XPRIM(100),XMPRE(100),DRVCYP(100),DRCYPL(100)
      DIMENSION XML(25),XMP2L(100)
      DIMENSION EY(25)
      DIMENSION D2YDX2(25), D2YDXP(100),DEV(25),DEVXP(100),G(25),GP(1
     100),BE(25),BE2(25),BEP(100),BE2P(100)
      DIMENSION D2CY(25),D2CYP(100)
      DIMENSION [illegible]
      DIMENSION [illegible]
      DIMENSION VP(2),YP(2),XMP(2)
      COMMON DELTX
      READ (5,150)IZERO
  150 FORMAT(I2)
      READ(5,100) [illegible]
      IF(ND.EQ. [illegible]
      IF ([illegible]
  100 FORMAT(I2,I4,I4,I3)
C
      READ(5,104)(DX(I),DY(I),I=1, [illegible]
  104 FORMAT( [illegible]
      [illegible]
      [illegible]
```

```
151   IF(I.GT.NP)GO TO 152
      IF(DX(I).EQ.0.)GO TO 150
      DX(J)=DX(I)
      DY(J)=DY(I)
      DZ(J)=DZ(I)
      J=J+1
150   I=I+1
      GO TO 151
152   NP=J-1
      I=1
      J=1
153   IF(I.GT.NP)GO TO 154
      IF(DY(I).EQ.0.)GO TO 156
      DX(J)=DX(I)
      DY(J)=DY(I)
      DZ(J)=DZ(I)
      J=J+1
156   I=I+1
      GO TO 153
154   NP=J-1
      IF(NP.EQ.0)STOP
      IF (NP.GT.50)STOP'NP.GT.50'
      WRITE(6,110)ND,IN,ITEMP,NP
110   FORMAT(//,5X,'DIODE NO. ',I2,5X,'IRRAD. NO.',I3,5X,'TEMPERATURE',I
     14,' DEG.K',5X,'NO.OF DATA POINTS IS',I4,//)
      TEMP=ITEMP
      XMP(1) =1.
      XMP(2)=10.
      YP(1)=DY(1)
      YP(2)=DY(1)
      VP(1)=0.2
      VP(2)=1.5
      DO 101 I=1,NP
C     DYL IS LOG OF DATA ORDINATE
      DYL(I)=ALOG(DY(I))
C     DXL IS LOG OF DATA ABSCISSA
      DXL(I)=ALOG (DX(I))
C
C     EY IS ERROR IN SUBR [illegible]
C
C
      EY(I)=.005*DYL(I)
101   CONTINUE
      S=NP
C     HAVE USED XM,BETA,[illegible],XMI AND [illegible] AS DUMMY VARIABLES
C     IN THE SMOOTH SUBROUTINE CALLS IN ORDER TO SAVE ARRAY SPACE.
      CALL SMOOTH(DX,DYL,[illegible],CXP,CYPL,[illegible],S,EY,D2LY,[illegible])
      DO 900 I=1,NP
900   EY(I)=.005*DRVCYL(I)
      CALL SMOOTH(DX,DRVCYL,XM,BETA,CXP,[illegible],S,EY,[illegible])
      DO 901 I=1,NP
      DRVCYL(I)=XM(I)
      D2LY(I)=BETA(I)
```

```
901   FY(I)=.0005*D2LY(I)
      DO 902 I=1,100
      DRCYPL(I)=XMPRIM(I)
      D2LYP(I)=BPRIM(I)
902   CONTINUE
      CALL SMOOTH(DX,D2LY,XP,BETA,CXP,XMPRIM,BPRIM,NP,S,FY,XPL,XMPCMI)
      DO 111 I=1,NP
      D2LY(I)=XP(I)
      CY(I)=EXP(CYL(I))
      DRVCY(I)=DY(I)*DRVCYL(I)
      D2YDX2(I)=DY(I)*(DRVCYL(I)*DRVCYL(I)+D2LY(I))
      G(I)=CY(I)*D2YDX2(I)/(DRVCY(I)*DRVCY(I))
      DFDX(I)=1.-G(I)
      HF(I)=100.*CY(I)/(.026*TEMP*DRVCY(I))
      HF2(I)=HF(I)*HF(I)
111   CONTINUE
      DO 112 I=1,100
      D2LYP(I)=XMPRIM(I)
      CYP(I)=EXP(CYPL(I))
      DRVCYP(I)=DRCYPL(I)*CYP(I)
      D2YDXP(I)=CYP(I)*(DRCYPL(I)*DRCYPL(I)+D2LYP(I))
      GP(I)=CYP(I)*D2YDXP(I)/(DRVCYP(I)*DRVCYP(I))
      DFDXP(I)=1.-GP(I)
      HFP(I)=100.*CYP(I)/(.026*TEMP*DRVCYP(I))
      HF2P(I)=HFP(I)*HFP(I)
      CXPL(I)=ALOG(CXP(I))
112   CONTINUE
      DO 113 I=2,100
      IF(DRCYPL(I))115,116,115
116   DRCYPL(I)=DRCYPL(I-1)
115   CONTINUE
      IF(DRVCYP(I))113,114,113
114   DRVCYP(I)=DRVCYP(I-1)
113   CONTINUE
      NPM=NP-1
      DO 120 I=1,NPM
      TMLY=HF(I)*HF2(I+1)-HF(I+1)*HF2(I)
      IF(TMLY)121,122,121
122   XM1(I)=0.
      XM2(I)=0.
      GO TO 120
121   SRM=(HF2(I+1)*G(I)-HF2(I)*G(I+1))/TMLY
      RDM=(HF(I+1)*G(I)-HF(I)*G(I+1))/TMLY
      TMLY=SRM*SRM-4.*RDM
      IF (TMLY)122,123,123
123   TMLY=SQRT(TMLY)
      IF(RDM)124,122,124
124   TMLY=1./(2.*RDM)
      XM2(I)=TMLY*(SRM+[illegible])
      XM1(I)=-[illegible]
      IF(I[illegible])125,126,125
125   WRITE(6,[illegible])
126   FORMAT([illegible],12,[illegible],I1,4,[illegible])
```

NOT REPRODUCIBLE

```
      XM1(I)=10.
126   IF(10.-ABS(XM2(I)))127,120,120
127   WRITE(6,129)I,XM2(I)
129   FORMAT('FOR I= ',I2,',XM2(I) WAS CHANGED FROM ',F11.4,' TO 10.0')
      XM2(I)=10.
120   CONTINUE
      XM1(NP)=10.
      XM2(NP)=10.
      DO 130 I=1,99
      TMLY=RFP(I)*RF2P(I+1)-RFP(I+1)*RF2P(I)
      IF (TMLY)131,132,131
132   IF (I-1) 135,135,136
135   XM1P(1)=1.
      XM2P(1)=1.
      WRITE(6,800)
800   FORMAT (/,'XM1P(1)AND XM2P(1) WERE SET=TO 1')
      GO TO 130
136   XM1P(I)=XM1P(I-1)
      XM2P(I)=XM2P(I-1)
      WRITE (6,801)I
801   FORMAT(/,'XM1P(I) AND XM2P(I)WERE SET EQUAL TO THEIR NEXT LOWER
     1VALUES FOR I= ',I2)
      GO TO 130
131   SRMP=(RF2P(I+1)*GP(I)-RF2P(I)*GP(I+1))/TMLY
      RPMP=(RFP(I+1)*GP(I)-RFP(I)*GP(I+1))/TMLY
      TMLY=SRMP*SRMP-4.*RPMP
      IF(TMLY)132,133,133
133   TMLY=SQRT(TMLY)
      IF (RPMP)134,132,134
134   TMLY1=1./(2.*RPMP)
      XM2P(I)=TMLY1*(SRMP-TMLY)
      XM1P(I)=-XM2P(I)+SRMP/RPMP
      IF(10.-ABS(XM1P(I)))140,141,141
140   WRITE (6,142)I,XM1P(I)
142   FORMAT('FOR I= ',I2,',XM1P(I) WAS CHANGED FROM ',F11.4,' TO 10.0')
      XM1P(I)=10.
141   IF (10.-ABS(XM2P(I)))143,144,144
143   WRITE(6,145)I,XM2P(I)
145   FORMAT('FOR I= ',I2,',XM2P(I) WAS CHANGED FROM ',F11.4,' TO 10.0')
       XM2P(I)=10.
144   CONTINUE
      IF(XM1P(I))804,130,130
804   TEMP1=-XM1P(I)
      XM1P(I)=XM2P(I)
      XM2P(I)=TEMP1
      WRITE(6,833)I
833   FORMAT('XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= ',I2,' AND TH
     1E SIGN OF THE NEW XM2P(I) WAS CHANGED')
130   CONTINUE
      XM1P(100)=10.
      XM2P(100)=10.
      TMLY=[illegible]/(.026*TF*P)
      DO 200 I=1,99
```

NOT REPRODUCIBLE

```
      IF(XM1P(I)-XM2P(I))701,702,701
702   IF(I-1)703,703,704
703   CYO1P(I)=0.
      CYO2P(I)=0.
      WRITE(6,705)
705   FORMAT(/,'CYO1P(I)AND CYO2P(I) WERE SET=TO 0')
      GO TO 700
704   CYO1P(I)=CYO1P(I-1)
      CYO2P(I)=CYO2P(I-1)
      WRITE (6,706)I
706   FORMAT(/,'CYO1P(I) AND CYO2P(I) WERE SET EQUAL TO THEIR NEXT LOWER
     1VALUES FOR I= ',I2)
      GO TO 700
701   IF(XM1P(I).EQ.0..OR.XM2P(I).EQ.0.)GO TO 702
      TMLY1=EXP(TMLY/XM2P(I))-EXP(TMLY/XM1P (I))
      IF((CXP(I)/(XM1P(I)*TEMP))-.0074)707,707,708
708   CYO1P(I)=0.
      WRITE(6,709)I
709   FORMAT(/,'CYO1P(I) WAS SET EQUAL TO ZERO FOR I= ',I2)
      GO TO 711
707   DEN1=TMLY1*EXP(300.*CXP(I)/(.026*TEMP*XM1P(I)))
      CYO1P(I)=(CYP(I)*EXP(TMLY/XM2P(I))-CYP(I+1))/DEN1
711   IF((CXP(I)/(XM2P(I)*TEMP))-.0074)712,712,713
713   CYO2P(I)=0.
      WRITE(6,714)I
714   FORMAT(  'CYO2P(I) WAS SET EQUAL TO ZERO FOR I= ',I2)
      GO TO 700
712   DEN2=TMLY1*EXP(300.*CXP(I)/(.026*TEMP*XM2P(I)))
      CYO2P(I)=(CYP(I+1)-CYP(I)*EXP(TMLY/XM1P(I)))/DEN2
700   CONTINUE
      CYO1P(100)=CYO1P(99)
      CYO2P(100)=CYO2P(99)
      DO 604 I=1,100
C     HPRIM(I) IS EQUIVALENT TO Q/MPRIM(I)KT
      HPRIM(I)=DRVCYP(I)/CYP(I)
C     CYPL IS LOG OF CYP
      CYPL(I)=ALOG(CYP(I))
C     PPRIM IS PRE-EXPONENTIAL FACTOR
      PPRIM(I)=EXP(CYPL(I)-HPRIM(I)*CXP(I))
C     XMPRIM IS MPRIM(I)
      XMPRIM(I)=300./(.026*TEMP*HPRIM(I))
      XMPRML(I)=ALOG(XMPRIM(I))
604   CONTINUE
      DO 607 I=1,NP
C     HETA(I) IS EQUIVALENT TO Q/M(I)KT
      HETA(I)=DRVCY(I)/CY(I)
C     CYL IS LOG OF CY
      CYL(I)=ALOG(CY(I))
C     P IS PRE-EXPONENTIAL FACTOR
      P(I)=EXP(CYL(I)-HETA(I)*CX(I))
      XM(I)=300./(.026*TEMP*HETA(I))
      XML(I)=ALOG(XM(I))
607   CONTINUE
```

NOT REPRODUCIBLE

```
      WRITE (6,270)
270   FORMAT(3X,'I',6X,'DZ')
      WRITE(6,271)(I,DZ(I),I=1,NP)
271   FORMAT(I4,F12.5)
105   WRITE(6,103)
103   FORMAT(3X,'I',5X,'DX',9X,'DY',9X,'DXL',8X,'DYL',8X,'CY',9X,'CYL',
     18X,'DRVCY',6X,'BETA',8X,'P',9X,'XM',9X,'XML')
107   WRITE(6,106)(I,DX(I),DY(I),DXL(I),DYL(I),CY(I),CYL(I),DRVCY(I),
     1BETA(I),P(I),XM(I),XML(I),I=1,NP)
106   FORMAT(I4,F11.4,8E11.4,2F11.4)
      WRITE (6,300)
300   FORMAT(/,3X,'I',4X,'DFDX',7X,'1-DFDX',5X,'HF',6X,'HFSQR',7X,'XM1',
     18X,'XM2')
      WRITE (6,301)(I,DFDX(I),G(I),HF(I),HF2(I),XM1(I),XM2(I),I=1,NP)
301   FORMAT (I4,4E11.4,2F11.4)
257   WRITE(6,259)
259   FORMAT(/,3X,'I',5X,'CXP',19X,'CXPL',18X,'CYP',6X,'CYPL',6X,
     1'DRVCYP',6X,'RPRIM',6X,'PPRIM',5X,'XMPRIM',5X,'XMPRML')
261   WRITE(6,260)(I,CXP(I),CXPL(I),CYP(I),CYPL(I),DRVCYP(I),RPRIM(I),
     1PPRIM(I),XMPRIM(I),XMPRML(I),I=1,100)
260   FORMAT(I4,F11.4,11X,E11.4,11X,5F11.4,2F11.4)
      WRITE(6,400)
400   FORMAT(/,3X,'I',4X,'DFDXP',6X,'1-DFDXP',4X,'HFP',7X,'HFSQRP',6X,'X
     1M1P',7X,'XM2P',6X,'CY01P',6X,'CY02P',6X,'D2YDXP',6X,'D2LYP')
      WRITE (6,401)(I,DFDXP(I),GP(I),HFP(I),HF2P(I),XM1P(I),XM2P(I),
     1CY01P(I),CY02P(I),D2YDXP(I),D2LYP(I),I=1,100)
401   FORMAT (I4,4E11.4,2F11.4,4F11.4)
      CALL PLOTIT (CXP,CYP,100,1)
      CALL PLOTIT (CXP,CYPL,100,1)
      CALL PLOTIT (CXP,DRVCYP,100,1)
      CALL PLOTIT (CXP,XMPRIM,100,1)
      CALL PLOTIT (CYP,XMPRIM,100,1)
      CALL PLOTIT (CYPL,XMPRIM,100,1)
      CALL PLOTIT(CYPL,XMPRML,100,1)
      CALL PLOTIT(CXP,XM1P,100,1)
      CALL PLOTIT(CXP,XM2P,100,1)
      CALL   PLOTIT(CXP,CY01P,100,1)
      CALL   PLOTIT(CXP,CY02P,100,1)
```

```
MEMORY MAP

PROCEDURES
 00004 = )NS4        12072 = )EFF        17230 = )ARG        17324 = )FLF        12451 = )STP
 16072 = )S16        17221 = )LRF        12576 = )CO1        16053 = ALOG        16175 = )M16
 12674 = SMOOTH      16204 = EXP         13146 = )A16        16043 = )D16        14501 = SQRT
 14944 = ABS         16003 = [illegible]  17334 = PLOTIT     17434 = [illegible]

LOCAL RELATIVE
 17541 = LTO.01      00101 = DZ          00163 = DX          00245 = [illegible]  00327 = DXL
 00411 = DYL         00473 = CY          00555 = CYL         00637 = P           00721 = BETA
 01003 = XM          01065 = DRVCY       01147 = DRVCYL      01231 = CXP         01541 = CYP
 02051 = CXPL        02361 = CYPL        02671 = RPRIM       03251 = PPRIM       03511 = XMPRIM
 04021 = DRVCYP      04331 = [illegible]  04641 = XML        04723 = XMPRML      05233 = FX
```

NOT REPRODUCIBLE

```
 05315 = 02YDX2     05377 = 02YDYP     05707 = DEDX       05771 = DEDXP      06301 = G
 06363 = GP         06673 = RF         16755 = RE2        07637 = REP        07347 = RE2P
 07667 = 02LY       07711 = 02LYP      10251 = XM1        10333 = XM2        10415 = XM1P
 10725 = XM2P       11235 = CYL1P      11545 = CYD2P      12655 = YP         12361 = YP
 12065 = XMP        17457 = TEMP       17473 = S          17500 = RTO,01     17506 = RTO,02
 17515 = TMLY       17517 = SRM        17521 = RDM        17525 = RTO,03     17531 = TMLY1
 17533 = SRMP       17535 = RDMP       17537 = TEMP1      17542 = RTO,04     17546 = DEN1
 17550 = DEN2       174370= I2EE       174400= [illegible] 17441 = IK        174420= ITEMP
 17443 = RP         17444 = I          17445 = ITO,01     17446 = ITO,02     17447 = I
 17452 = ITO,03     17451 = ITO,04     17454 = ITO,05     17455 = ITO,06     17475 = ITO,07
 17476 = ITO,08     17477 = ITO,09     17502 = ITO,10     17503 = ITO,11     17512 = ITO,12
 17513 = ITO,13     17514 = RDM

LOCAL DYNAMIC

ABSOLUTE

STMNT LABELS
 12105 = 000160     12155 = 000100     12216 = 000104     12230 = 000151     12327 = 000152
 12323 = 000150     12336 = 000153     12434 = 000154     12430 = 000156     12510 = 000110
 12664 = 000101     12713 = 000900     12776 = 000901     13044 = 000902     13233 = 000111
 13411 = 000112     13467 = 000113     13443 = 000115     13430 = 000116     13454 = 000114
 14127 = 000120     13560 = 000121     13542 = 000122     13661 = 000123     13667 = 000124
 13736 = 000125     14025 = 000126     13761 = 000128     14043 = 000127     14063 = 000129
 15076 = 000130     14375 = 000131     14215 = 000132     14221 = 000135     14264 = 000136
 14237 = 000800     14324 = 000801     14500 = 000133     14507 = 000134     14556 = 000140
 14645 = 000141     14601 = 000142     14663 = 000143     14747 = 000144     14703 = 000145
 14760 = 000804     15014 = 000811     16005 = 000700     15337 = 000701     15156 = 000702
 15154 = 000703     15224 = 000704     15176 = 000705     15266 = 000706     15524 = 000707
 15450 = 000708     15472 = 000709     15615 = 000711     15712 = 000712     15642 = 000713
 15661 = 000714     16126 = 000604     16234 = 000607     16250 = 000270     16507 = 000271
 16314 = 000105     16322 = 000103     16406 = 000107     16520 = 000106     16543 = 000300
 16665 = 000301     16626 = 000252     16704 = 000259     16772 = 000261     17073 = 000260
 17124 = 000400     17326 = 000401

COMMON
 000000= DELTY

 17554 = RANGE
                    END
```

NOT REPRODUCIBLE

```
      SUBRØUTINE SMØØTH(X,Y,R,R1,CXP,RPRIM,R1PRIM,N,S,DY,R2,R2PRIM)
C
C     ABSTRACT
C        SMØØTH FITS A SMØØTH SPLINE THRØUGH THE GIVEN SET ØF DATA
C        BY MINIMIZING THE INTEGRAL ØF THE SECØND DERIVATIVE SUBJECT
C        TØ THE CØNSTRAINT THAT
C               N
C              SUM ( (R(I)-Y(I))/DY(I))**2 ) .LE. S.
C              I=1
C
C     DESCRIPTIØN ØF ARGUMENTS
C        N   - NUMBER ØF DATA VALUES
C        X   - ABSCISSA ARRAY
C        Y   - ØRDINATE ARRAY
C        DY  - WEIGHT ARRAY.  IF S=N, DY(I) SHØULD BE AN ESTIMATE
C              ØF THE ERRØR IN Y(I).
C        S   - SCALE FACTØR FØR WEIGHTS, NØRMALLY = N.
C        A,B,C,D - CUBIC BETWEEN X(I) AND X(I+1) IS
C              A(I) + B(I)*H + C(I)*H**2 + D(I)*H**3
C              WHERE H IS DESIRED ABSCISSA MINUS X(I).
C        R   - ARRAY ØF SMØØTH SPLINE VALUES
C        R1  - ARRAY ØF SMØØTH SPLINE DERIVATIVES
C        R2  - ARRAY ØF SMØØTH SPLINE SECØND DERIVATIVES
C        T,T1,U,V - WØRK ARRAYS
C
C        X,Y,DY,A,B,C,D MUST BE DIMENSIØNED AT LEAST N
C        R,R1,R2,T,T1,U,V MUST BE DIMENSIØN AT LEAST N+2
C
C     REFERENCE -- NUMERISHE MATHEMATIK 10,177-183 (1967) C H REINSCH
C     CØNVERSIØN FRØM THE ALGØL BY R E JØNES, DIV 9422, SANDIA LABS
C     THE ØRIGINAL N1 WAS FIXED AT 1 TØ AVØID WASTED WØRK ARRAY SPACE
C     THE ØRIGINAL N2 IS CALLED N HERE
C     ALL WØRK ARRAY INDICES ARE 1 LARGER THAN IN THE ALGØL,
C     TØ AVØID A ZERØ SUBSCRIPT.
C
C     PRØGRAM HAS BEEN MØDIFIED TØ CALCULATE CXP,RPRIM AND R1PRIM WITH-
C     IN THE PRØGRAM, INSTEAD ØF ØUTSIDE...P. [illegible],12/1/70
C
      DIMENSIØN X(25),Y(25),DY(25)
      DIMENSIØN R(25),R1(25),R2(25),T(25),T1(25),U(25),V(25),A(25),
     1B(25),C(25),D(25)
      DIMENSIØN CXP(100),RPRIM(100),R1PRIM(100)
      DIMENSIØN Z(100)
      DIMENSIØN R2PRIM(100)
      CØMMØN DELTX
C
C     INITIALIZE
C
      R(1) = 0.0
      R(2) = 0.0
      R1(N+1) = 0.0
      R2(N+1) = 0.0
      R2(N+2) = 0.0
```

NOT REPRODUCIBLE

```
      U(1) = 0.0
      U(2) = 0.0
      U(N+1) = 0.0
      U(N+2) = 0.0
      P = 0.0
      M2 = N-1
C
      H = X(2)-X(1)
      F = (Y(2)-Y(1))/H
      DO 100 I=2,M2
      G = H
      H = X(I+1)-X(I)
      E = F
      F = (Y(I+1)-Y(I))/H
      A(I) = F-E
      T(I+1) = 2.0*(G+H)/3.0
      T1(I+1) = H/3.0
      R2(I+1) = DY(I-1)/G
      R(I+1) = DY(I+1)/H
  100 R1(I+1) = -DY(I)/G - DY(I)/H
C
      DO 200 I=2,M2
      B(I)= R(I+1)*R(I+1) + R1(I+1)*R1(I+1) + R2(I+1)*R2(I+1)
      C(I)= R(I+1)*R1(I+2) + R1(I+1)*R2(I+2)
  200 D(I)= R(I+1)*R2(I+3)
      F2  = -S
C
C     NEXT ITERATION
C
  250 DO 300 I=2,M2
      R1(I) = F*R(I)
      R2(I-1) = G*R(I-1)
      R(I+1)=1.0/(P*B(I)+T(I+1)-F*R1(I)-G*R2(I-1))
      U(I+1)=A(I)-R1(I)*U(I)-R2(I-1)*U(I-1)
      F = P*C(I)+T1(I+1)-H*R1(I)
      G = H
  300 H = D(I)*P
C
      DO 400 I=2,M2
      I=M2-(I-2)
  400 U(I+1)=R(I+1)*U(I+1)-R1(I+1)*U(I+2)-R2(I+1)*[illegible](I+3)
      E=0.0
      H=0.0
C
      DO 500 I=1,M2
      G = H
      H = (U(I+2)-U(I+1))/(X(I+1)-X(I))
      V(I+1) = (H-G)*DY(I)*DY(I)
  500 E = E+V(I+1)*(H-G)
      V([illegible]+1) = -H*DY([illegible])*DY([illegible])
      [illegible] = [illegible]([illegible]+1)
      E = [illegible]
      [illegible] = [illegible]
```

NOT REPRODUCIBLE

```
      F2= F+P*P
      IF ((F2.GE.S).OR.(F2.LE.G)) GO TO 650
      F = 0.
      H = (V(3)-V(2))/(X(2)-X(1))
C
      DO 600 I=2,M2
      G = H
      H = (V(I+2)-V(I+1))/(X(I+1)-X(I))
      G=H-G-R1(I)*R(I)-R2(I-1)*R(I-1)
      F = F+G*R(I+1)*G
  600 R(I+1) = G
      H = E-P*F
      IF (H.LE.0.0) GO TO 650
      P = P+(S-F2)/((SQRT(S/E)+P)*H)
      GO TO 250
C
C     FINISH
C
  650 DO 700 I=1,N
      A(I)=Y(I)-P*V(I+1)
  700 C(I)=U(I+1)
C
      DO 800 I=1,M2
      H=X(I+1)-X(I)
      D(I)=(C(I+1)-C(I))/(3.0*H)
  800 B(I)=(A(I+1)-A(I))/H-(H*D(I)+C(I))*H
      B(N)=0.0
      D(N)=0.0
C
C     OUTPUT DERIVATIVES, ETC.
C
      DO 900 I=1,M2
      R(I) = A(I)
      R1(I) = B(I)
  900 R2(I) = 2.0*C(I)
      R(N) = A(N)
      H = X(N)-X(M2)
      R1(N)=(3.0*D(M2)*H+2.0*C(M2))*H+B(M2)
      R2(N)=6.0*D(M2)*H+2.0*C(M2)
C
C     DELTX IS INCREMENT 'DELTA X' ON X AXIS
C
      DELTX =(X(N)-X(1))/99.
      K=0
      DO 201 I=1,100
C
      CXP(I)    = X(1)+K*DELTX
      K=K+1
201   CONTINUE
      I=1
      DO 302 I=1,100
333   IF (CXP(I)    .GE. X(I+1)) GO TO 301
302   CONTINUE
```

NOT REPRODUCIBLE

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          Z(J)=EXP(T)-X(J)
          RPRIME(I)=A(I)+Z(J)*(B(I)+Z(J)*(C(I)+D(I)*Z(J)))
          R1PRIM(I)=B(I)+Z(J)*(2.*C(I)+3.*D(I)*Z(J))
          R2PRIM(I)=2.*C(I)+6.*D(I)*Z(J)
          GO TO 305
    301   I=I+1
          GO TO 302
    305   IF (I.LE.M) GO TO 308
          GO TO 304
    308   CONTINUE
    304   RETURN

MEMORY MAP

PROCEDURES
 00004 = )SSA         03046 = )I16         03147 = )D16         03333 = )A16         03324 = )M16
 02476 = )NG1         02527 = [illegible]  03160 = )C01         03412 = [illegible]

LOCAL RELATIVE
 03506 = LTO,01       03414U= X            03415U= Y            03410 = R            03417 = R1
 03420 = EXP          03421 = RPRIME       03422 = R1PRIM       03424U= S            03425U= DY
 03426 = R2           03427 = R2PRIM       00035 = T            00117 = T1           00201 = U
 00263 = V            00345 = A            00427 = B            00511 = C            00573 = D
 00655 = Z            000000= [illegible]  03441 = P            03446 = H            03452 = F
 03455 = G            03457 = E            03465 = RTO,01       03467 = RTO,02       03471 = RTO,03
 03473 = F2           03477 = RTO,04       03503 = RTO,05       03423U= F            03443 = M2
 03430 = ITO,01       03433 = ITO,02       03434 = ITO,03       03435 = ITO,04       03436 = ITO,05
 03437 = ITO,06       03442 = ITO,07       03444 = ITO,08       03445 = ITO,09       03450 = ITO,10
 03451 = ITO,11       03453 = J            03501 = ITO,12       03502 = ITO,13       03505 = I
 03513 = K

LOCAL DYNAMIC

ABSOLUTE

STMNT LABELS
 01431 = [illegible]  01554 = 000200       01605 = 000250       02000 = 000310       02026 = [illegible]
 02176 = 000050       02541 = 000550       02456 = 000600       02571 = 000700       02652 = [illegible]
 02776 = [illegible]  03171 = 000301       03401 = 000308       03201 = 000333       03361 = [illegible]
 03225 = 000302       03365 = 000305       03407 = 000304

COMMON
 00000 = DELTX


 03514 = RANGE
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NOT REPRODUCIBLE

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NEXT JOB
X

    DIODE NO. 32     IRRAD. [illegible]     TEMPERATURE 300 DEG.K     NO. OF DATA POINTS IS   9

FOR I=  1,XM1P(I) WAS CHANGED FROM     33.8333 TO 10.0
FOR I=  2,XM1P(I) WAS CHANGED FROM     22.6774 TO 10.0
FOR I=  3,XM1P(I) WAS CHANGED FROM     1[illegible].0976 TO 10.0
FOR I= 22,XM1P(I) WAS CHANGED FROM     12.2167 TO 10.0
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 23 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 24 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 25 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 26 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 27 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 28 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 29 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 30 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 31 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
FOR I= 97,XM1P(I) WAS CHANGED FROM    -73.4035 TO 10.0
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 98 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
XM1P(I) AND XM2P(I) WERE INTERCHANGED FOR I= 99 AND THE SIGN OF THE NEW XM2P(I) WAS CHANGED
  I      DZ
  1  .00000E 00
  2  .00000E 00
  3  .00000E 00
  4  .00000E 00
  5  .00000E 00
  6  .00000E 00
  7  .00000E 00
  8  .00000E 00
  9  .00000E 00
  I      DX          DY            [illegible]        CYI           CY           CYI          DRVLY        BETA          P              XM         XMI
  1     .400     .2250E 04  -.[illegible]E [illegible]  .7710E 01  .2250E 04  .7712E 01  .4341E 05  .1[illegible]E 02  .[illegible]6E 01   1.[illegible]33     .6898
  2     .500     .1550E 05  -.6031E [illegible]  .9649E 01  .1550E 05  .9649E 01  .2304E 06  .1[illegible]E 02  .0249E 00   1.9921     .6892
  3     .600     .1070E 06  -.51[illegible]E 00   .1158E 02  .1070E 06  .1158E 02  .2066E 07  .1433E 02  .0634E 00   1.9[illegible]     .6861
  4     .700     .7420E 06  -.4567E 00   .1352E 02  .7405E 06  .1352E 02  .1437E 08  .1[illegible]41E 02  .0294E 00   1.9614     .6636
  5     .[illegible]     .5342E 07  -.2231E 00   .1549E 02  .5208E 07  .1545E 02  .1781E 09  .2[illegible]E 02  .1132E 00   1.8654     .6342
  6     .[illegible]     .4730E 08  -.1[illegible]E 00   .1767E 02  .4793E 08  .1769E 02  .1174E 10  .2413E 02  .1267E-01   1.5717     .4515
  7    1.[illegible]     .8210E 09   .7154E-0[illegible]  .2053E 02  .8363E 09  .2154E 02  .2660E 11  .3141E 02  .1281E-0[illegible]   1.2091     .1[illegible]49
  8    1.[illegible]     .2922E 11   .0533E-01  .2411E 02  .9877E 11  .2408E 02  .1031E 13  .3703E 02  .2173E-07   1.0139     .[illegible]138
  9    1.2[illegible]     .1320E 13   .[illegible]E 00   .2791E 02  .1313E 13  .2790E 02  .5[illegible]85E 14  .3[illegible]2E 02  .6023E-[illegible]     .9657    -.0144

  I    [illegible]       1-[illegible]       [illegible]         [illegible]          XM1         [illegible]2
  1 -.3142E-04   .1[illegible]E 01   .1[illegible]E 01   .3[illegible]3E 01      1.9050      1.74[illegible]
  2 -.4[illegible]58E-03   .1[illegible]E 01   .1[illegible]2E 01   .3962E 01      1.9054      1.6[illegible]
  3 -.6[illegible]75E-[illegible]3   .10[illegible]E 01   .1900E 01   .39[illegible]E 01      1.9016      1.14[illegible]
  4 -.2308E-02   .1[illegible]2E 01   .1966E 01   .3942E 01      1.9886       .8[illegible]
  5 -.5780E-[illegible]   .1054E 01   .1[illegible]E 01   .3611E 01      2.0534      1.[illegible]7[illegible]
  6 -.[illegible]99E [illegible]   .1110E 01   .156[illegible]E 01   .24[illegible]2E 01      1.9522      1.[illegible]
  7 -.6700E-0[illegible]   .1[illegible]67E 01   .1187E 01   .1[illegible]E 01      1.74[illegible]       .[illegible]
  8 -.1962E-[illegible]   .1[illegible]2[illegible]E 01   .[illegible]E 01   .1[illegible]E 01       .3551       .[illegible]
  9 -.2348E-[illegible]   .1[illegible]E 01   .[illegible]   .[illegible]      1.[illegible]      1.
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NOT REPRODUCIBLE

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 I    CXP         CXPI          CYP        CYPI        DRVCYP       HPRIM       PPRIM       YMPRIM    XMPRML
 1   .4000    -.9163E 00    .2250E 04   .7719E 01   .4441E 05   .1930E 02   .1001E 01   1.9933    .6898
 2   .4081    -.8963E 00    .2630E 04   .7875E 01   .5074E 05   .1930E 02   .1000E 01   1.9932    .6898
 3   .4162    -.8767E 00    .3073E 04   .8031E 01   .5931E 05   .1930E 02   .9998E 00   1.9931    .6897
 4   .4242    -.8574E 00    .3592E 04   .8186E 01   .6932E 05   .1930E 02   .9994E 00   1.9930    .6897
 5   .4323    -.8386E 00    .4198E 04   .8342E 01   .8102E 05   .1930E 02   .9989E 00   1.9929    .6896
 6   .4404    -.8201E 00    .4906E 04   .8498E 01   .9469E 05   .1930E 02   .9985E 00   1.9928    .6896
 7   .4485    -.8019E 00    .5734E 04   .8654E 01   .1107E 06   .1930E 02   .9980E 00   1.9927    .6895
 8   .4566    -.7840E 00    .6702E 04   .8810E 01   .1294E 06   .1930E 02   .9975E 00   1.9926    .6894
 9   .4646    -.7665E 00    .7833E 04   .8966E 01   .1512E 06   .1930E 02   .9970E 00   1.9925    .6894
10   .4727    -.7492E 00    .9156E 04   .9122E 01   .1767E 06   .1930E 02   .9965E 00   1.9924    .6893
11   .4808    -.7323E 00    .1070E 05   .9278E 01   .2066E 06   .1931E 02   .9960E 00   1.9923    .6893
12   .4889    -.7156E 00    .1251E 05   .9434E 01   .2415E 06   .1931E 02   .9954E 00   1.9922    .6892
13   .4970    -.6992E 00    .1462E 05   .9590E 01   .2823E 06   .1931E 02   .9948E 00   1.9920    .6892
14   .5051    -.6831E 00    .1709E 05   .9746E 01   .3300E 06   .1931E 02   .9942E 00   1.9919    .6891
15   .5131    -.6672E 00    .1997E 05   .9902E 01   .3857E 06   .1931E 02   .9936E 00   1.9918    .6890
16   .5212    -.6516E 00    .2335E 05   .1006E 02   .4509E 06   .1931E 02   .9929E 00   1.9916    .6890
17   .5293    -.6362E 00    .2729E 05   .1021E 02   .5271E 06   .1931E 02   .9922E 00   1.9915    .6889
18   .5374    -.6211E 00    .3190E 05   .1037E 02   .6161E 06   .1931E 02   .9915E 00   1.9914    .6888
19   .5455    -.6061E 00    .3729E 05   .1053E 02   .7203E 06   .1932E 02   .9907E 00   1.9912    .6887
20   .5535    -.5914E 00    .4359E 05   .1068E 02   .8421E 06   .1932E 02   .9899E 00   1.9911    .6887
21   .5616    -.5769E 00    .5096E 05   .1084E 02   .9844E 06   .1932E 02   .9891E 00   1.9909    .6886
22   .5697    -.5626E 00    .5957E 05   .1099E 02   .1151E 07   .1932E 02   .9882E 00   1.9907    .6885
23   .5778    -.5486E 00    .6964E 05   .1115E 02   .1346E 07   .1932E 02   .9873E 00   1.9906    .6884
24   .5859    -.5347E 00    .8140E 05   .1131E 02   .1573E 07   .1932E 02   .9863E 00   1.9904    .6883
25   .5939    -.5210E 00    .9516E 05   .1146E 02   .1839E 07   .1933E 02   .9853E 00   1.9902    .6882
26   .6020    -.5075E 00    .1112E 06   .1162E 02   .2150E 07   .1933E 02   .9842E 00   1.9900    .6881
27   .6101    -.4941E 00    .1301E 06   .1178E 02   .2514E 07   .1933E 02   .9831E 00   1.9898    .6880
28   .6182    -.4810E 00    .1520E 06   .1193E 02   .2939E 07   .1933E 02   .9818E 00   1.9896    .6879
29   .6263    -.4680E 00    .1778E 06   .1209E 02   .3437E 07   .1933E 02   .9805E 00   1.9894    .6878
30   .6343    -.4552E 00    .2078E 06   .1224E 02   .4018E 07   .1934E 02   .9790E 00   1.9891    .6877
31   .6424    -.4425E 00    .2430E 06   .1240E 02   .4698E 07   .1934E 02   .9773E 00   1.9888    .6876
32   .6505    -.4300E 00    .2841E 06   .1256E 02   .5494E 07   .1934E 02   .9753E 00   1.9885    .6874
33   .6586    -.4177E 00    .3321E 06   .1271E 02   .6425E 07   .1935E 02   .9730E 00   1.9882    .6872
34   .6667    -.4055E 00    .3883E 06   .1287E 02   .7514E 07   .1935E 02   .9705E 00   1.9877    .6870
35   .6747    -.3934E 00    .4541E 06   .1303E 02   .8788E 07   .1935E 02   .9675E 00   1.9873    .6868
36   .6828    -.3815E 00    .5310E 06   .1318E 02   .1028E 08   .1936E 02   .9642E 00   1.9867    .6865
37   .6909    -.3697E 00    .6209E 06   .1334E 02   .1202E 08   .1936E 02   .9604E 00   1.9861    .6862
38   .6990    -.3581E 00    .7262E 06   .1350E 02   .1407E 08   .1937E 02   .9561E 00   1.9855    .6859
39   .7071    -.3466E 00    .8493E 06   .1365E 02   .1646E 08   .1938E 02   .9511E 00   1.9847    .6855
40   .7152    -.3353E 00    .9934E 06   .1381E 02   .1926E 08   .1939E 02   .9442E 00   1.9836    .6849
41   .7232    -.3240E 00    .1162E 07   .1397E 02   .2255E 08   .1940E 02   .9340E 00   1.9821    .6841
42   .7313    -.3129E 00    .1360E 07   .1412E 02   .2642E 08   .1943E 02   .9190E 00   1.9798    .6830
43   .7394    -.3019E 00    .1592E 07   .1428E 02   .3099E 08   .1946E 02   .8979E 00   1.9766    .6813
44   .7475    -.2911E 00    .1865E 07   .1444E 02   .3637E 08   .1950E 02   .8694E 00   1.9720    .6790
45   .7556    -.2803E 00    .2186E 07   .1460E 02   .4275E 08   .1956E 02   .8327E 00   1.9661    .6761
46   .7636    -.2697E 00    .2563E 07   .1476E 02   .5033E 08   .1964E 02   .7873E 00   1.9586    .6722
47   .7717    -.2591E 00    .3007E 07   .1492E 02   .5933E 08   .1973E 02   .7334E 00   1.9493    .6675
48   .7798    -.2487E 00    .3531E 07   .1508E 02   .7008E 08   .1985E 02   .6715E 00   1.9381    .6617
49   .7879    -.2384E 00    .4151E 07   .1524E 02   .8294E 08   .1998E 02   .6031E 00   1.9247    .6548
50   .7960    -.2282E 00    .4883E 07   .1540E 02   .9837E 08   .2015E 02   .5400E 00   1.9091    .6466
51   .8040    -.2181E 00    .5750E 07   .1556E 02   .1169E 09   .2034E 02   .4538E 00   1.8911    .6372
52   .8121    -.2081E 00    .6780E 07   .1573E 02   .1394E 09   .2056E 02   .3804E 00   1.8708    .6264
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NOT REPRODUCIBLE

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 53     .8202          -.1982E 00          .8106E 07  .1593E 02  .1666E 09  .2081E 02  .3101E 00     1.8684      .6143
 54     .8283          -.1884E 00          .9471E 07  .1605E 02  .1997E 09  .2109E 02  .2463E 00     1.8241      .6011
 55     .8364          -.1787E 00          .1124E 08  .1623E 02  .2402E 09  .2139E 02  .1905E 00     1.7970      .5865
 56     .8444          -.1691E 00          .1335E 08  .1641E 02  .2900E 09  .2173E 02  .1435E 00     1.7701      .5710
 57     .8525          -.1596E 00          .1591E 08  .1658E 02  .3514E 09  .2209E 02  .1051E 00     1.7409      .5544
 58     .8606          -.1501E 00          .1901E 08  .1676E 02  .4276E 09  .2249E 02  .7493E-01     1.7104      .5368
 59     .8687          -.1408E 00          .2281E 08  .1694E 02  .5225E 09  .2291E 02  .5195E-01     1.6780      .5182
 60     .8768          -.1315E 00          .2746E 08  .1713E 02  .6414E 09  .2336E 02  .3501E-01     1.6465      .4987
 61     .8848          -.1223E 00          .3319E 08  .1732E 02  .7913E 09  .2384E 02  .2293E-01     1.6134      .4784
 62     .8929          -.1132E 00          .4030E 08  .1751E 02  .9811E 09  .2435E 02  .1459E-01     1.5798      .4573
 63     .9010          -.1042E 00          .4915E 08  .1771E 02  .1223E 10  .2488E 02  .9012E-02     1.5457      .4355
 64     .9091          -.9531E-01          .6024E 08  .1791E 02  .1533E 10  .2545E 02  .5410E-02     1.5115      .4131
 65     .9172          -.8646E-01          .7419E 08  .1812E 02  .1932E 10  .2603E 02  .3165E-02     1.4773      .3902
 66     .9253          -.7769E-01          .9183E 08  .1834E 02  .2446E 10  .2664E 02  .1810E-02     1.4437      .3672
 67     .9333          -.6899E-01          .1142E 09  .1855E 02  .3114E 10  .2726E 02  .1016E-02     1.4108      .3441
 68     .9414          -.6037E-01          .1428E 09  .1878E 02  .3983E 10  .2790E 02  .5617E-03     1.3788      .3212
 69     .9495          -.5183E-01          .1794E 09  .1901E 02  .5119E 10  .2853E 02  .3070E-03     1.3479      .2985
 70     .9576          -.4335E-01          .2265E 09  .1924E 02  .6608E 10  .2918E 02  .1666E-03     1.3183      .2763
 71     .9657          -.3495E-01          .2874E 09  .1948E 02  .8568E 10  .2981E 02  .9012E-04     1.2900      .2547
 72     .9737          -.2661E-01          .3665E 09  .1972E 02  .1116E 11  .3045E 02  .4880E-04     1.2632      .2337
 73     .9818          -.1835E-01          .4697E 09  .1997E 02  .1459E 11  .3107E 02  .2657E-04     1.2380      .2135
 74     .9899          -.1015E-01          .6051E 09  .2022E 02  .1917E 11  .3167E 02  .1462E-04     1.2143      .1942
 75     .9980          -.2023E-02          .7834E 09  .2048E 02  .2527E 11  .3226E 02  .8160E-05     1.1922      .1758
 76    1.0061           .6041E-02          .1019E 10  .2074E 02  .3346E 11  .3282E 02  .4644E-05     1.1718      .1585
 77    1.0141           .1404E-01          .1333E 10  .2101E 02  .4447E 11  .3336E 02  .2700E-05     1.1529      .1423
 78    1.0222           .2198E-01          .1751E 10  .2128E 02  .5930E 11  .3387E 02  .1606E-05     1.1355      .1271
 79    1.0303           .2985E-01          .2309E 10  .2156E 02  .7935E 11  .3436E 02  .9770E-06     1.1194      .1128
 80    1.0384           .3766E-01          .3059E 10  .2184E 02  .1065E 12  .3482E 02  .6090E-06     1.1047      .0996
 81    1.0465           .4542E-01          .4065E 10  .2213E 02  .1433E 12  .3525E 02  .3891E-06     1.0912      .0873
 82    1.0545           .5311E-01          .5422E 10  .2241E 02  .1933E 12  .3565E 02  .2552E-06     1.0788      .0759
 83    1.0626           .6074E-01          .7254E 10  .2270E 02  .2613E 12  .3603E 02  .1718E-06     1.0676      .0654
 84    1.0707           .6832E-01          .9732E 10  .2300E 02  .3540E 12  .3637E 02  .1190E-06     1.0575      .0559
 85    1.0788           .7584E-01          .1309E 11  .2329E 02  .4802E 12  .3669E 02  .8476E-07     1.0483      .0472
 86    1.0869           .8330E-01          .1764E 11  .2359E 02  .6523E 12  .3697E 02  .6221E-07     1.0402      .0394
 87    1.0949           .9071E-01          .2382E 11  .2389E 02  .8870E 12  .3723E 02  .4707E-07     1.0331      .0325
 88    1.1030           .9806E-01          .3222E 11  .2420E 02  .1207E 13  .3746E 02  .3675E-07     1.0268      .0265
 89    1.1111           .1054E 00          .4365E 11  .2450E 02  .1643E 13  .3765E 02  .2961E-07     1.0215      .0213
 90    1.1192           .1126E 00          .5920E 11  .2480E 02  .2239E 13  .3782E 02  .2456E-07     1.0170      .0169
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 94    1.1515           .1411E 00          .2024E 12  .2603E 02  .7743E 13  .3826E 02  .1486E-07     1.0052      .0052
 95    1.1596           .1481E 00          .2757E 12  .2634E 02  .1057E 14  .3833E 02  .1376E-07     1.0035      .0035
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 97    1.1758           .1619E 00          .5127E 12  .2696E 02  .1970E 14  .3842E 02  .1228E-07     1.0010      .0010
 98    1.1838           .1688E 00          .6996E 12  .2727E 02  .2691E 14  .3846E 02  .1177E-07     1.0000      .0000
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  2 -.2660E-03  .1000E 01  .1003E 01  .1073E 01    10.0000     1.9893  .1475E 01  .9820E 00  .9794E 06  .9986E-01
  3 -.2236E-03  .1000E 01  .1003E 01  .1073E 01    10.0000     2.0000 -.2794E 01  .1032E 01  .1145E 07  .8341E-01
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NOT REPRODUCIBLE

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50 -.5442E-01  .1054E 01  .1909E 01  .3644E 01   2.0305    .9990  .1298E 01  .1512E-07  .2090E 10  .2209E 02
51 -.6123E-01  .1061E 01  .1891E 01  .3576E 01   2.0366   1.0186  .1354E 01  .2776E-07  .2524E 10  .2533E 02
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NOT REPRODUCIBLE

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 87 -.2124E-01   .1021E 01  .1034E 01  .1067E 01    1.7907     .9839  .1560E 00  .5409E-08  .3372E 14  .2944E 02
 88 -.1871E-01   .1019E 01  .1027E 01  .1054E 01    1.8153     .9845  .2067E 00  .5634E-08  .4606E 14  .2626E 02
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NOT REPRODUCIBLE

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1. B. W. Noel, C. E. Barnes, and H. D. Southward, "Neutron Irradiation Effects on Diffused GaAs Laser Diodes," Bureau of Engineering Research, The University of New Mexico, Technical Report No. EE-186(71)ONR-005, September 1971.

2. L. W. Aukerman and M. F. Millea, Phys. Rev. 148, 759 (1966).